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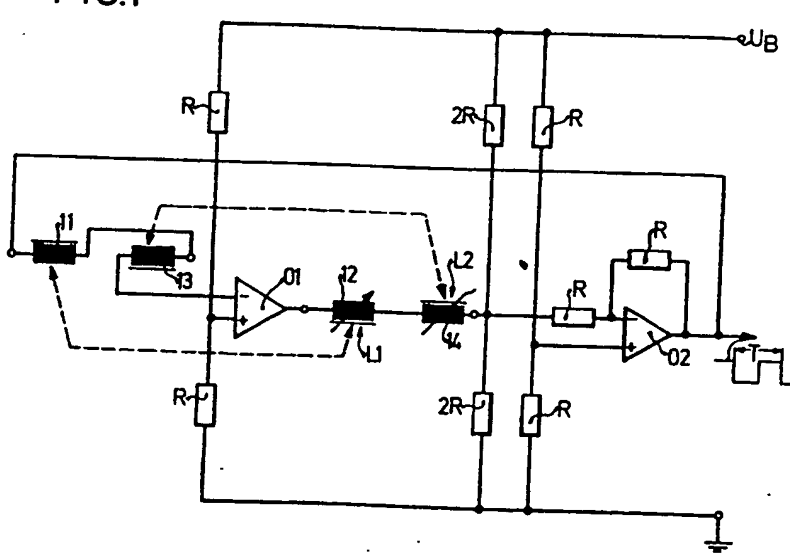
(54) Inductive Measuring Apparatus for a Controlling or Regulating Member, in Particular of an Internal Combustion Engine

(57) The measuring coil (L1) and the reference coil (L2) of a short-circuit-ring transducer connected to an evaluating circuit are each divided into mutually magnetically coupled measurement windings (11 and 12) and mutually magnetically coupled reference windings (13 and 14). The evaluation circuit includes at least two operational amplifiers (O1 and O2) connected as shown to produce a square wave output whose period T is proportional to (L1—L2)/R.

FIG.1



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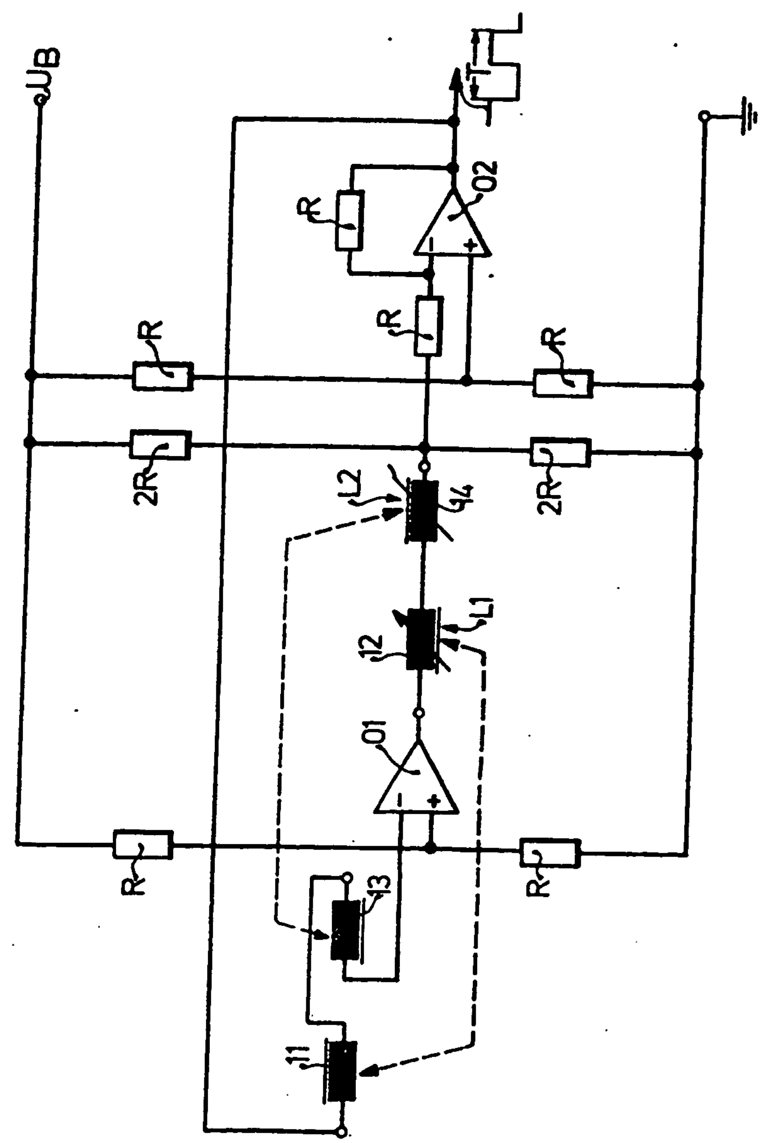

FIG.1

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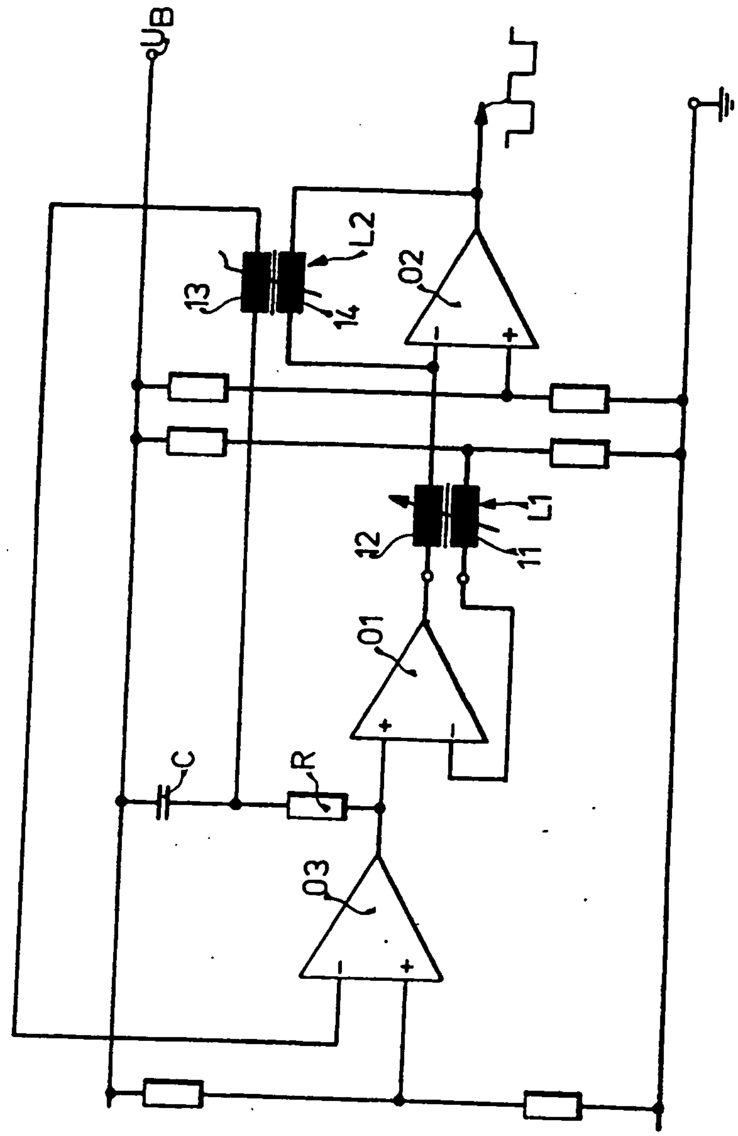

FIG.2

SPECIFICATION

Inductive Measuring Apparatus for a Controlling or Regulating Member, in Particular of an Internal Combustion Engine

The invention relates to inductive measuring apparatus for the detection of the displacement of a controlling or regulating member, such as a controlling or regulating member associated with an internal combustion engine, comprising a short-circuit-ring transducer, which has a first coil whose (measurement) inductance is variable in dependence on the respective position of the magnetic flux short-circuit-ring, and a second coil having an independent (reference) inductance, the coils being connected to an electrical evaluation circuit in order to log the variable inductance.

In electronic diesel-engine control systems, for logging linear and angular displacements, for example, of the fuel quantity regulating rod of a fuel injection pump, it is possible to use short-circuit-ring transducers in which the short-circuit-ring is mechanically coupled to the controlling or regulating member and performs identical movement thereto. The short-circuit-ring is displaceable along two parallel arms of a magnetic core, on which the coils are wound, so as to vary the length and thereby the reluctance of the magnetic flux path linking the measurement coil. Thus inductance of the measuring coil is varied in accordance with the displacement to be logged.

It is an object of the present invention to achieve, in a measuring apparatus of the above-mentioned type, a variation in inductance for detecting as accurately as possible the actuating or controlling quantity, and to provide a simple circuit arrangement for evaluation of the variations in inductance.

The present invention resides in inductive measuring apparatus for the detection of the displacement of a controlling or regulating member which comprises a short-circuit-ring transducer, having a first coil whose (measurement) inductance is variable in dependence on the respective position of a magnetic flux short-circuit-ring and a second coil having an independent (reference) inductance, and an electrical evaluation circuit to which the coils are connected in order to log the variable inductance, and in which the first coil of variable inductance, is sub-divided into two magnetically coupled measuring windings, and the second coil of the reference inductance is sub-divided into two magnetically coupled reference windings, and the evaluation circuit has at least two serially arranged operational amplifiers the output of each of which is regeneratively connected or coupled to an inverting input, one of the two measuring windings being connected to the inverting input of the first operational amplifier and the other of the two measuring windings being arranged in a connection between the output of the first operational amplifier and the inverting input of the second operational amplifier.

The invention is further described, by way of example, with reference to the drawings in which:—

Figs. 1 and 2 are of two embodiments of inductive measuring apparatus according to the invention.

The measuring apparatus shown serves to detect the displacement of a fuel quantity regulating rod (not shown) of a diesel-engine fuel injection pump of an internal combustion engine, and comprises a half-differential short-circuit-ring transducer (not shown in detail), whose magnetic flux short-circuit-ring is mechanically coupled to the controlling or regulating member to be monitored.

The short-circuit-ring transducer is provided with two magnetically-coupled measuring windings 11 and 12, and two reference windings 13 and 14, which are also magnetically coupled and have a fixed inductance L2. In contrast to these reference windings, the inductance L1 of the two measuring windings is varied between a maximum value and a minimum value according to the position of the short-circuit-ring.

As is evident from the circuit diagram of Figure 1, the evaluation circuit comprises a first operational amplifier O1 and a second operational amplifier O2 serially connected thereto, both of which are maintained at half the operating voltage U_B at their non-inverting inputs by means of voltage dividers formed by equally-sized resistors of value R.

In the junction line between the output of the first operational amplifier O1 and a resistor R connected to the inverting input of the second operational amplifier O2 there is connected the series combination of the second measuring winding 12 and the second reference winding 14. The latter is connected to the supply voltage U_B and to earth via respective integrating resistors of value 2R. In order to achieve regenerative feedback, the first two winding halves 11 and 13, which are individually magnetically coupled respectively to the second measuring winding 12 and the second reference winding 14, are connected in a feedback circuit which is connected between the inverting input of the first operational amplifier O1 and the output of the second operational amplifier O2, so that at the output of the second operational amplifier there is produced a square-wave oscillation whose period T is directly proportional to the difference between the measured inductance L1 and the reference inductance L2, namely:

$$T = \text{const} \frac{L1 - L2}{R}$$

In the embodiment of Figure 2, a third operational amplifier O3, whose non-inverting input is connected to a fraction of the operating voltage U_B, is serially connected to the input of the first operational amplifier O1. To the inverting

input of the operational amplifier O3 there is connected the first reference winding 13, whose other end is connected to the junction between a capacitor C, which is directly connected to the operating voltage U_B, and a resistor R connected to the output of the third operational amplifier O3. The output of the third operational amplifier O3 is directly connected to the non-inverting input of the first operational amplifier O1. The output of the first operational amplifier O1 is connected by way of the second measuring winding 12 to the inverting input of the second operational amplifier O2 which in turn is connected via the second reference winding 14 to the output of the second operational amplifier O2. The first measuring winding 11, on the other hand, is connected to the inverting input of the first operational amplifier O1, its other end being connected to a fraction of the operating voltage U_B.

Owing to the feedback, a square-wave oscillation, whose frequency

$$f=\text{const}\frac{L1}{L2},$$

is produced at the output of the second operational amplifier O2. The output voltage of the second operational amplifier can therefore be further directly processed by digital means, as is the case with the embodiment of Figure 1.

The particular advantage of the invention lies in the fact that the output voltages can be further processed directly by digital means. Furthermore, owing to the transformer-type coupling of the transducer inductances the effects of temperature on the individual inductances are eliminated. The control signals of the transducer inductances may closely approach the supply voltage U_B, that is, they may have an amplitude

$$\sim\pm\frac{U_B}{2},$$

so that a good signal-to-noise ratio is consequently achieved in the event of long connecting leads being used between the transducer and the evaluation circuit.

Claims

1. Inductive measuring apparatus for the detection of the displacement of a controlling or regulating member which comprises a short-circuit-ring transducer, having a first coil whose (measurement) inductance is variable in dependence on the respective position of a magnetic flux short-circuit-ring and a second coil having an independent (reference) inductance, and an electrical evaluation circuit to which the coils are connected in order to log the variable inductance, and in which the first coil of variable inductance, is sub-divided into two magnetically coupled measuring windings, and the second coil of the reference inductance is sub-divided into two magnetically coupled reference windings, and the evaluation circuit has at least two serially arranged operational amplifiers the output of each of which is regeneratively connected or coupled to an inverting input, one of the two measuring windings being connected to the inverting input of the first operational amplifier and the other of the two measuring windings being arranged in a connection between the output of the first operational amplifier and the inverting input of the second operational amplifier.

2. Measuring apparatus as claimed in claim 1, in which the first of the two reference windings is connected in series with the first of the two measuring windings, and this series circuit is arranged between the output of the second operational amplifier and the inverting input of the first operational amplifier, and in which the second reference winding is connected in series with the second measuring winding and this latter series circuit is connected to the output of the first operational amplifier.

3. Measuring apparatus as claimed in claim 1, in which the inverting input of a third operational amplifier, whose non-inverting input is connected to a fraction of the operating voltage, is connected to one end of the first reference winding and the output of the third operational amplifier is connected to the non-inverting input of the second operational amplifier, and via a resistor to the other end of the first reference winding and to a capacity connected to the operating voltage, and in which the second reference winding is connected between the inverting input and the output of the second operational amplifier and one end of the second measuring winding is connected to the inverting input of the first operational amplifier, its other end being connected to a fraction of the operating voltage.

4. Inductive measuring apparatus constructed and adapted to operate substantially as herein described with reference to and as illustrated in the drawings.

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